The flood mapping using SAR data

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Part 1:
Fundamentals in the flooding mapping using SAR
Identification of the open water surface

Due to the smooth water surface in general, the SAR backscatter from the surface should be low. The water surface from rivers/streams or water bodies should be dark on a SAR image.
Identification of the water under tree canopies

Due to the double-bounced trunk-ground surface interactions in forested areas, an enhanced SAR backscatter is observed when the forests are flooded. In the inland flooding, the enhance SAR backscattering is typically noted along river/stream channels or immediate uplands near water bodies. The bright signature helps the delineation of the flooded vs. non-flooded area. Furthermore, the enhanced SAR backscattering is especially strong or clear on a SAR image with a long wavelength (such as L-band with a wavelength of 24 cm.)

Double-bounced trunk-ground interactions
- Given the same amount of incoming radar energy

@ air-ground interface:
- Surface, rough
- Dielectric constant, low
- Penetration into ground, some (to none)
- Water underneath trees: less diffused scattering at smooth surface, and more specularly reflected scattering due to high $\varepsilon_r$ → An enhanced double-bounced trunk-ground interactions

SAR images – wetlands/swamps along river/stream channels

Tar River within Pitt County, NC
PALSAR, L-HH, 02/05/2011

Virginia Beach, VA
PALSAR, L-HH, 05/19/07
Software and SAR data requirements

**Data Analysis software:** To avoid intellectual property and software licensing issues, the public domain software SNAP® developed by European Space Agency (ESA) is used in this handout. The SNAP is downloadable at [http://step.esa.int/main/toolboxes/snap/](http://step.esa.int/main/toolboxes/snap/)

**SAR datasets:** In addition to the SAR datasets that a user may have, there are freely downloadable SAR data. In this handout, the Sentinel-1 SAR data are considered and exampled. For the flooding mapping, the SAR data before a flood event and another SAR data during or immediate after the flood event are needed. The Sentinel-1 SAR data can be downloaded at the ESA web site, [https://scihub.copernicus.eu/dhus/#/home](https://scihub.copernicus.eu/dhus/#/home) or the ASF (Alaska Satellite Facility) web site, [https://vertex.daac.asf.alaska.edu/](https://vertex.daac.asf.alaska.edu/). For a USA user, it is recommended to use the ASF web site because it is fast to download the data.
A computer
This is the computer used for this handout.
End of Part 1
This slide is deliberately empty.
Part 2:
Analyzing the Sentinel-1 ground range detected (GRD) data using the SNAP© software.

The 2018 Wilmington NC flood is exampled.
The current Sentinel-1 GRD data are not readily usable without several steps of data processing.
The interface of SNAP© software

1. This is the default interface when you open the SNAP software the first time.
2. There are many layers and subwindows. The software remembers the settings when you exit. Click “Windows/Reset Windows” to get the default settings.
Load the data (without unzipping the file): drag and drop the zipped file into Product Explorer dialog box. Then, open the Bands folder and double-click each band (one at a time) to view the amplitude and intensity data. The Intensity VV is shown as an example.

The SAR data were acquired along an ascending orbit.
Extract the area of interest (AOI)

• In most cases, one considers the AOI. Then, the subset of the SAR is next. Here, the Wilmington area, NC is extracted as an example.
Load the data (without unzipping the file): drag and drop the zipped file into “Product Explorer” dialog box. Then, open the “Bands” folder and double-click each band (one at a time) to view the amplitude and intensity data. The Intensity_VV is shown as an example.

Right-click inside the viewer to open the drop down menu. Select Spatial Subset from View… (next slide)
Extract the area of interest (AOI)

**Hint:** You can run this couple of times until your AOI is correctly extracted. Since you are using the data before the flood and the data during or after the flood, it is recommended that you extract the AOI as large as possible.

Click OK to subset
The AOI of the Wilmington area, NC
The Intensity_VV subimage is shown as an example
• ESA delivers SAR data once acquired. Even though the “Orbit state vectors” are included in the zipped data file downloaded, ESA reprocesses the orbit state vectors with the high level of accuracy. The time lapse is about 20 days. Thus, the orbit state vectors should be re-downloaded and updated. This is especially true when the InSAR analysis is conducted.
• However, two possible situations that you may not able to download and use the “Orbit state vectors” if
  • the Internet connection is not available or
  • your data are too new to have the revised “Orbit state vectors” available at
    • https://qc.sentinel1.eo.esa.int/aux_poeorb/?page=1
When I was working on this handout on 5 April 2019, the POD Precise Orbit Ephemerides [AUX_POEORB] were available for data collected on 17 March 2019 or early.
Click “Radar/Apply Orbit File” to open Apply Orbit File dialog box (next slide)
Make the selections as shown and save the files to where you want to save. Make sure that the subimage is used. (wilmington is used as an example.)

Notes: The default settings are to use the new orbit file. Thus, check this option if you want to run this procedure without the update of the orbit parameters or you do not have the Internet connection.

Click Run to proceed

With or without the revised orbit state vector, the program will run and create output.
The Intensity_VV subimage with the revised orbit data
Click “Radar/Radiometric/Calibrate” to open its dialog box. Accept the defaults. Open “Processing Parameters” and make selections. Then click “Run” to proceed. Once completed, click “Close” to go to next step.

Make sure that the subimage is used.

beta0 only!
The beta0_VV subimage
Click “Radar/Radiometric/Radiometric Terrain Flattening” to open its dialog box. In this process, the topographic effect on the SAR image (layover and foreshortening) will be removed. Accept the defaults. Open “Processing Parameters” and select both bands. Then click “Run” to proceed. Once completed, click “Close” to go to next step.

Note: You need to get online for this step.
The gamma0_VV subimage after the radiometric terrain flattening
The gamma0_VH subimage after the radiometric terrain flattening
Click “Radar/Geometric/Terrain Correction/Range-Doppler Terrain Correction”
to open its dialog box (next slide)
1. Click Processing Parameters

2. Make the (minimum) selections

If you are interested in other types of outputs, you can select them.

3. Click to proceed
These were caused due to no reliable DEM data over water surface.
Gamma0_VH subimage
Gamma0_VV subimage (acquired on 19 Sept. 2018). The 2018 flood event was in course.

The bright signature along river/stream channels or water bodies were flooded in addition to the dark signature of open water surface that is a part of the flooded area as well. Also, see the pre-flood SAR image (next slide).
Save the folders and files for future use. Collapse the opened folders in the “Product Explorer” window first. Then from the bottom to top, one-by-one right-click to open the drop down menu selecting “Save Product” and then “Close Product” (next slide).
This is the input zipped file. You do not need to save it. Click × to quit the SNAP software.
In SAR data analysis, the conversion from the linear scale to log scale and vice versa is common.
Conversion from the linear scale to log scale. 
For the intensity data: $10\log_{10}(x)$
For the amplitude data: $20\log_{10}(x)$.

(The intensity is proportional to the amplitude squared.)

Open the terrain correct image. From the top menu bar, click “Raster/Data Conversion/Linear to/from dB to open its dialog box. Select Gamma0_VH and Gamma0_VV.
Gamma0 VV subimage acquired on 19 Sept. 2018. The flooded event is during the course. The data is in log scale or dB.

The bright signature along river/stream channels or water bodies were flooded in addition to the dark signature of open water surface that is a part of the flooded area as well. Also, see the pre-flood SAR image (next slide).
Create GoogleEarth KMZ file using the log-scaled data. You can use the linear scale data as well.

Right-click within the viewer window to open the drop down menu. Select “Export View as GoogleEarth KMZ” and name and save the file to the folder you prefer.
The GoogleEarth KMZ file showing the flooded areas and their locations.
The SAR data used in this part were acquired during the course of the 2018 flood event near Wilmington, NC. One needs to process another pre-flood SAR data similarly. Thus, the flood mapping can be done with confidence.
End of Part 2
This slide is deliberately empty.
Part 3: Flood mapping

An image before the flood event, and another image during or immediate after the flood event are needed
Gamma0_VV subimage acquired on 13 Sept. 2018 (before the 2018 Wilmington flood event).
The data is in linear scale.
Gamma0_VV subimage acquired on 19 Sept. 2018. The flood event was in course. The data is in linear scale.

The bright signature along river/stream channels or water bodies were flooded in addition to the dark signature of open water surface that is a part of the flooded area as well.
Gamma0_VV subimage acquired on 13 Sept. 2018 (before the flood event) in log10 scale or dB.
Gamma0\_VV subimage acquired on 19 Sept. 2018. The flooded event was in course. The data is in log scale or dB.

The bright signature along river/stream channels or water bodies were flooded in addition to the dark signature of open water surface that is a part of the flooded area as well.
Create GoogleEarth KMZ file

Right-click within the viewer window to open the drop down menu. Select “Export View as GoogleEarth KMZ” and name and save the file to folder you prefer.
The GoogleEarth KMZ file showing the flooded areas and their locations.
End of Part 3